Moreau, Semiconductor Litography
Plenum
1988.

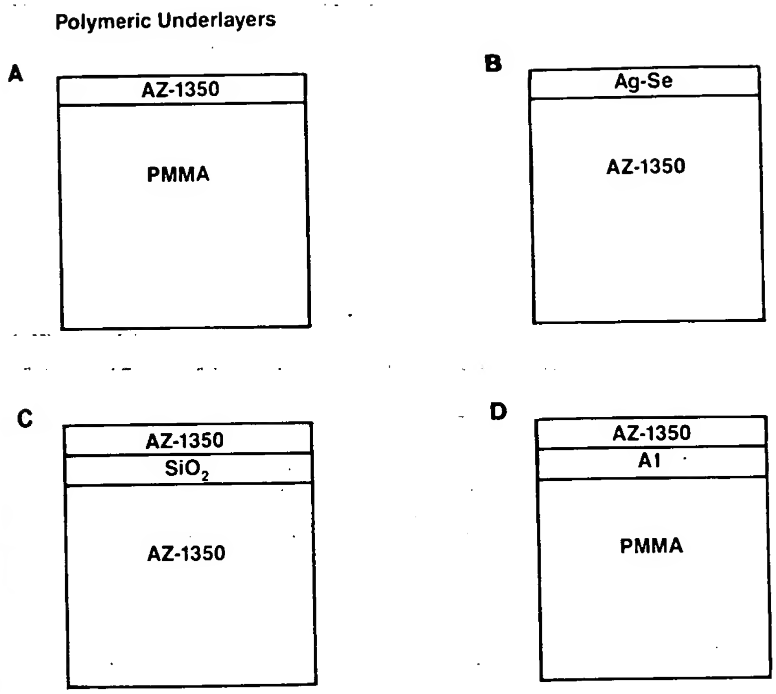

FIGURE 13-13-8. Some examples of bilayer and trilayer resist images that can be used for reactive ion etching. (A) From Ref. 758. (B) From Ref. 759. (C) From Ref. 760. (D) From Ref. 761.

underlayer erosion are desired. Furthermore, etch rate monitors are absolutely essential to terminate etching at each film sublayer.

By varying the power frequency and pressure, optimization of the throughput can be achieved.[385] Since sputter yields for Si, Si_3N_4, and SiO_2 are about equivalent for the same ion bombardment,[354] the chemical reactivity of Si, SiO_2, and Si_3N_4 to halogens, halocarbons, or halo etchants determines the selectivity ratio of film (F) to underlayer (U), (Table 13-13-17). For example, Kushner varied the Cl/F ratio in favor of a high Si/SiO_2 selectivity.[386] The high selectivity of SiO_2/Si is the major objective of the plasma etch process (to mimic HF wet etch). In order to accomplish high selectivity, the H/F ratio is manipulated in CF_4–H_2,[382] C_2F_6–C_2H_4,[394] and CHF_3.[395] There are three basic mechanisms of

TABLE 13-13-16. Resist-Plasma Selectivity

Film (F)	Resist (R)	F/R	Etchant	Reference
Si_3N_4	AZ-2400	10	CF_4	381
SiO_2	AZ-1350	5	C_2F_6	294
SiO_2	AZ-1350	10	CF_4/H_2	382
SiO_2	PMMA	4	CF_4/H_2	365
Poly Si	AZ-1470	5	NF_3	383
Poly Si	PBS	15	CF_4	356
PSG	AZ-1350	10	SF_6	384

TABLE 13-13-17. Selectivity (F/U) in Plasma Etching of Silicon

Film (F)	Underlayer (U)	F/U	Etchant	Reference
SiO_2	Si	20	H_2	387
SiO_2	Si	30	CF_4/H_2	388
SiO_2	Si	30	CF_3Cl	351
SiO_2	Si	8	HF	326
SiO_2	Si	5	C_2F_6	294
SiO_2	*p*-doped Si	20	CHF_3	389
Si	SiO_2	30	SF_6	390, 391
n-doped Si	Si	15	C_2F_5Cl	351
Poly Si	SiO_2	10	CF_4	392
Poly Si	SiO_2	14	NF_3	383
Poly Si	SiO_2	10	CCl_4	383
Si_3N_4	SiO_2	30	C_2F_6	393
Si_3N_4	SiO_2	12	CF_4/O_2	323
Si_3N_4	SiO_2	50	NF_3	398

SiO_2/Si selectivity: (1) a sidewall banking agent of polyvinyl fluoride film forms on the Si by growth from adsorbed C[698]:

$$CF_3(ads) + Si \rightarrow C(ads) + SiF \qquad (13\text{-}13\text{-}13)$$

$$C(ads) + CF_x \rightarrow Poly(CF_x) \qquad (13\text{-}13\text{-}14)$$

Excess H_2 generates carbon and a polymer deposits on all surfaces,[395] which requires a subsequent Cl_2/Ar cleanup.[396, 682] CHF_3/SiF_6 is recommended as a gas that forms little residue.[384, 707] In deep trench CF_4 etching of 0.2-μm-wide by 6-μm-deep holes in silicon, deposits of polymer build up on the orifice and eventually stop the etching.[751] (2) The second mode involves adjustment of the concentration of F* and CF_3^+. While the etch rate of Si will depend on the F* concentration, the etching of SiO_2 mainly involves the sputter-assisted reactions of CF_3^+. (3) Differences in the chemisorption of the etching gases have also been proposed as a basic mechanism for selectivity.[302] Br generated[523] from CF_3Br is suggested to adsorb preferentially on SiO_2, and inhibit F attack by inducing F atom dimerization.[397]

For active devices, the etchant attack of the Si layer underneath the SiO_2 remains a problem for shallow junction devices. A combination of mixed etching techniques serves to prevent the Si attack.[524] Initially, the plasma etching of the oxide to the last 500-Å thickness is performed. Wet etching with HF removes the remaining film of SiO_2, and any contamination, such as heavy metal left on the silicon surface.

Choosing selective etching gases and conditions remains a basic challenge to the plasma chemist, especially for future reactors using rapid single-wafer etching,[389] where overetching must be counteracted by a high selectivity ratio (>20).

13-13-4. *Etch Profiles and Image Bias*

The image etch bias is the loss of sidewall material beyond the edge of resist (Fig. 13-13-9). The biases of wet etching were as large (2–4 μm) as the dimensions